

# Crossfit Practice: An Electromyographic Analysis of Masticatory Muscles

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## Research article

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# Abstract

**Background:** CrossFit is a regular high-intensity physical conditioning exercise for skeletal striated muscles, which promotes functional changes in the human body. The aim of this study was to investigate the impact of CrossFit exercise on the electromyographic activity of the masseter and temporalis muscles.

**Methods:** Forty participants were divided into two groups: athletes who practiced CrossFit (n=20) and controls who did not practice sports (n=20). The electromyographic activities of the masseter and temporalis muscles were measured using mandibular tasks at rest, protrusion, right laterality, left laterality, and dental clenching in maximum voluntary contraction and habitual chewing of peanuts and raisins. Both the groups were matched for age, sex, and body mass index. The data were analyzed using the t-test with a 5% significance level.

**Results:** Reduced electromyographic activities were found in all mandibular tasks in the CrossFit group than in the control group, with a significant difference for the right masseter ( $p=0.01$ ), left masseter ( $p=0.001$ ), and left temporal muscles ( $p=0.001$ ) at mandibular rest; right ( $p=0.001$ ) and left ( $p=0.001$ ) masseter in chewing of peanuts.

**Conclusion:** The results of this study suggest that CrossFit promotes positive changes in electromyographic activity of the masticatory muscles, especially in the mandibular rest and chewing of hard food. CrossFit exercise practiced within the appropriate technical protocols improves masticatory muscle function.

## Background

CrossFit is a high-intensity functional sports training exercise most practiced in the world [1], and is associated with elements of aerobic conditioning with dynamic movements, which promotes strength, power, cardiovascular and respiratory resistance, agility, flexibility, and quick physical conditioning [2, 3].

Sportive exercise has been gaining popularity in the last 10 years, which is reflected by the number of followers of this practice, present in 142 countries [4]. In Brazil, it is widely publicized, and it is estimated that more than 40,000 athletes practice this sport [5, 6].

Studies have evaluated the influence of CrossFit exercise on the neuromuscular system, mainly on the anatomical relationship of the spine with the dynamic structures of the human body, with the occurrence of injuries, overload, and muscle fatigue [7–9].

In turn, the masticatory system has the ability to adapt to biomechanics with constant change; and the occlusal and mandibular positioning changes, for example, can affect an athlete's functional performance [10]. Several factors influence craniofacial characteristics, and it is accepted that sports exercises contribute to possible changes in the structures of the stomatognathic system [11].

This study provides scientific evidence regarding the influence of CrossFit exercise on the performance of masticatory muscles in athletes, through the analysis of the functional performance of masticatory muscles. There is a lack of studies in the literature on the evaluation proposed in this study. Therefore, we aimed to analyze the electromyographic activity of the masseter and temporalis muscles, in order to demonstrate the impact of sports on the functionality of the stomatognathic system. An alternative hypothesis of this study is that CrossFit exercise alters masticatory function.

## Methods

### Participants

The post-hoc test was performed at an  $\alpha$  level of 0.05, and a power ( $\pi$ ) of 0.99 for the main result of the mandibular task at rest to confirm the sample size (20 participants in each group) using the G\* Power 3.0.10 program (Franz Faul, Kiel, Germany). The mean  $\pm$  standard deviation (SD) of the electromyographic activity of the left masseter muscle was  $0.04 \pm 0.03$  for the group of athletes practicing CrossFit, whereas that of the control group was  $0.12 \pm 0.07$ , producing an effect size of 1.48.

Out of a total of 60 participants who were evaluated and fulfilled the eligibility selection criteria; 20 participants of both sexes who practiced CrossFit exercise (mean  $\pm$  SD,  $30.8 \pm 4.4$  years) for at least two years were included in this study. The control group that did not exercise (mean  $\pm$  SD,  $30.0 \pm 5.7$  years) was composed of 20 participants matched for age, sex, and body mass index. The characteristics of the participants in both groups are shown in Table 1.

Table 1  
Data on the characteristics of the two groups.

Groups	Age	BMI
GI	$30.8 \pm 4.4$	$25.1 \pm 2.7$
GII	$30.0 \pm 5.7$	$23.3 \pm 3.5$
p - value	NS	NS
GI, CrossFit athletes group; GII, group not practicing the exercise; BMI, body mass index; * significant difference, student's t test ( $p < .05$ ); NS: not significant.		

All participants met the following inclusion criteria: normal occlusion, absence of temporomandibular disorder according to the RDC / TMD [12], nonsmoker, without muscle injuries in the last 5 months, without cardiovascular and neurological diseases and not using medication and/or dietary supplements that could alter muscle function.

### Electromyographic Analysis

The electromyographic activity of the masseter and temporalis muscles was used to determine the electromyographic activity of MyoSystem-I P84 (Uberlândia, Minas Gerais, Brazil). The surface electrodes were positioned on the muscular bellies following the standards recommended by the protocol SENIAM [13]. Before placing the electrodes on the surface of the cutaneous tissue, cleaning with alcohol was performed to decrease the myoelectric impedance [14].

Muscle activity was measured by means of electromyographic records (microvolts/second) of mandibular tasks according to the standard established by the electromyography laboratory from the University [15, 16]. Dental clenching during maximum voluntary contraction was used to normalize the electromyographic data.

At the time of data collection, the participants remained seated in comfortable chairs, in upright posture, feet flat on the floor, and palms flat on their thighs. The Frankfurt's horizontal plane was kept parallel to the ground [16, 17].

## Method Errors

The random error was determined using Dahlberg's formula [18]. Five participants were evaluated during two different sessions, with an interval of seven days in between. A small variation was observed in the electromyographic measurements between the first and second sessions for the electromyograph with surface electrodes (3.74%).

## Data analysis

Data were analyzed using the Statistical Package for the Social Sciences Software (IBM Corp. IBM SPSS Statistics for Windows, version 22.0: IBM Corp). The Shapiro-Wilk test was applied to verify the normal distribution of the data. Student's t test was performed to analyze differences between groups. The level of significance adopted was  $p < 0.05$ , with a 95% confidence level. Means and standard errors were used as descriptive statistics.

## Results

Table 2 shows the difference between the group of athletes who practiced CrossFit and the group of participants who did not practice the sport. In comparison, the normalized electromyographic values of the group performing the CrossFit exercise were significantly lower in the mandibular rest position for the right masseter muscle ( $p = 0.01$ ), left masseter muscle ( $p = 0.001$ ), left temporal muscle ( $p = 0.001$ ); and chewing of peanuts for the right ( $p = 0.001$ ) and left ( $p = 0.001$ ) masseter muscles.

Table 2  
Normalized electromyographic data of masticatory muscles in mandibular tasks.

<b>Mandibular tasks</b>	<b>G1</b>	<b>GII</b>	<b>p value</b>
Total sample size	20	20	NA
Variables - muscles			
Rest - RM	0.04 ± 0.01	0.13 ± 0.03	0.01*
Rest - LM	0.04 ± 0.01	0.12 ± 0.01	0.00*
Rest - RT	0.07 ± 0.01	0.12 ± 0.02	0.03*
Rest - LT	0.09 ± 0.04	0.12 ± 0.02	NS
Protrusion - RM	0.18 ± 0.05	0.29 ± 0.06	NS
Protrusion - LM	0.18 ± 0.04	0.27 ± 0.05	NS
Protrusion - RT	0.12 ± 0.03	0.13 ± 0.02	NS
Protrusion - LT	0.11 ± 0.05	0.12 ± 0.02	NS
Right laterality - RM	0.09 ± 0.03	0.16 ± 0.04	NS
Right laterality - LM	0.12 ± 0.03	0.18 ± 0.03	NS
Right laterality - RT	0.13 ± 0.03	0.16 ± 0.02	NS
Right laterality - LT	0.09 ± 0.04	0.11 ± 0.02	NS
Left laterality - RM	0.11 ± 0.05	0.21 ± 0.04	NS
Left laterality - LM	0.13 ± 0.04	0.14 ± 0.02	NS
Left laterality - RT	0.09 ± 0.03	0.12 ± 0.02	NS
Left laterality - LT	0.10 ± 0.04	0.16 ± 0.03	NS
Chewing peanuts - RM	0.50 ± 0.07	0.97 ± 0.11	0.001*
Chewing peanuts - LM	0.53 ± 0.05	0.98 ± 0.12	0.001*
Chewing peanuts - RT	0.60 ± 0.09	0.81 ± 0.09	NS
Chewing peanuts - LT	0.53 ± 0.07	0.75 ± 0.10	NS
Chewing raisins - RM	0.47 ± 0.09	0.68 ± 0.11	NS
Chewing raisins - LM	0.44 ± 0.06	0.59 ± 0.09	NS
Chewing raisins - RT	0.48 ± 0.07	0.54 ± 0.06	NS
G1, CrossFit athletes group; GII, group not practicing the exercise; MRI, right masseter; LM, left masseter; RT, right temporal; LT, left temporal; * significant difference, student's t test (p < .05); NA: not applicable (paired samples); NS: not significant.			

Mandibular tasks	GI	GII	p value
Chewing raisins - LT	0.52 ± 0.08	0.55 ± 0.07	NS
GI, CrossFit athletes group; GII, group not practicing the exercise; MRI, right masseter; LM, left masseter; RT, right temporal; LT, left temporal; * significant difference, student's t test (p < .05); NA: not applicable (paired samples); NS: not significant.			

## Discussion

The results of this study determined the positive impact of CrossFit exercise on the masticatory muscles of athletes who practiced this modality when evaluating electromyographic activity, showing that the initial hypothesis was accepted.

The results of the analysis of the head and neck musculature are unprecedented and contradict the data reported in the literature that relate CrossFit exercise with injuries in the dynamic structures in the human body, especially if practiced incorrectly [19, 20]. It was possible to observe how the stomatognathic system behaved when practicing sports, mainly because many athletes contract the facial muscles and clench their teeth during maximum strength movements, which can trigger myofunctional changes [21].

In sports training, it is necessary to consider the effectiveness of skeletal muscle activity and assess body response in relation to pre-established exercise, observing strength, endurance, and muscle activity [22, 23]. Therefore, it is justifiable to evaluate the electromyographic behavior of the masseter and temporalis muscles of participants who practice CrossFit exercise to understand whether there is a relationship between high-intensity sports and the functionality of the dynamic structures of the stomatognathic system.

The masticatory musculature is composed of types I and II muscle fibers; muscular contraction of the motor units of these muscles is related to the oxidative enzyme activity, and is carried out through the action potential generated by the motor neurons present in the muscle cells [24]. The muscle's ability to promote strength depends on the number of cross-bridges between the actin and myosin filaments, transforming chemical energy into mechanics, resulting in balanced dynamic movement [25].

Physical training has the function of favoring the remodeling of the proteins that make up the skeletal striated musculature, providing molecular adaptations, and improving mitochondrial breathing [26], which results in better physical performance with increased resistance to fatigue and reduced muscle activity [27]. The stimulation of muscle contractions in athletes who practice CrossFit more precisely activates the molecular pathways inside the cells, regulating muscle plasticity to such an extent that the mechanical tension produced by physical effort establishes more appropriate physiological adaptations.

Here, we observed that in all mandibular tasks there was a reduction of normalized electromyographic activity in the group of athletes practicing CrossFit compared to the group that did not practice, with

significant difference at rest position and in the dynamic movement of chewing consistent food (peanuts).

In the mandibular rest position, there were significant differences between the two groups with reduced electromyographic activity of the masseter muscles and right temporal muscle for the group of athletes who practiced CrossFit. A hypothesis that explains the reduction in muscle activity would be the dynamics of arterial blood flow and the supply of oxygen and nutrients in the tissues of the human body. High-intensity training stimulates blood circulation and promotes more effective microcirculation [2], which results in an increase in oxygen in muscle cells, thus promoting relaxation of the human skeletal muscle after training, making it more functional [28].

When evaluating the dynamic movements of the stomatognathic system, especially the usual clinical condition of chewing, it is known that to affect and regulate the contractility of the skeletal muscle, thin filament proteins respond to calcium ( $\text{Ca}^{2+}$ ) [29, 30] and high-intensity aerobic training. In addition, there is an increase in the availability of the divalent cation ion inside the cells [31], promoting a stimulus for the release of neurotransmitters, contracting the muscles with proliferation of potential of action [32] that assists in the dynamic functional performance of the human body.

The results of this study demonstrated that the group of athletes who practiced CrossFit showed less electromyographic activity in the usual chewing of consistent food (peanuts); there was a significant difference for masseter muscles, which showed better chewing efficiency, owing to the lower recruitment of muscle fibers to perform the same dynamic movement when compared to the group that did not practice the sport [33].

The study has few limitations. The  $\text{Ca}^{2+}$  concentration inside the cells and the blood flow inside the arteries could not be measured, which are the factors that could more accurately determine the positive performance of the muscles of high-performance athletes. As it is a training that is becoming popular in the world and with increasing followers, the sample size could have influenced the significance of the results. Future studies, mainly relating to the mentioned limitations to occlusal morphology and strength, will provide more details on the functionality of the stomatognathic system of athletes who play high intensity sports, such as CrossFit.

A strength of the present study was the quality of the methodology that is internationally recognized and that assesses the masticatory muscles. Another strength was the test power of 99% of the sample size showing that the number of individuals analyzed represents the population of athletes who practice CrossFit.

## Conclusion

The findings of this study suggest that CrossFit promotes positive changes in the electromyographic activity of the masticatory muscles, especially in the mandibular rest position and chewing of consistent

food. Sports training as a physical conditioning that involves coordinated actions establishes a functional balance in the human body.

## **Abbreviations**

RDC/TMD - Research Diagnostic Criteria for Temporomandibular Disorders

SENIAM - Surface Electromyography for the Noninvasive Assessment of Muscles

## **Declarations**

# **Declarations**

## **Ethics Approval and Consent to Participate**

The study was reviewed and approved by the ethics committee of the School of Dentistry of Ribeirão Preto, University of São Paulo, SP, Brazil (process # 19828619.5.0000.5419). All participants were informed about the protocol and potential risks and signed an informed consent form. Authors declare that the study reported were performed in accordance with the ethical standards of the Helsinki Declaration.

## **Consent to publish**

Not applicable.

## **Availability of data and materials**

All data generated or analyzed during this study are included in this manuscript.

## **Competing interests**

The authors declare that they have no competing interests.

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## **Authors' contributions**

NS, SCHR, SS, JECH, MP, EDV and EMF made substantial contributions to project conception, design, data acquisition, curation, analysis and interpretation, research tool construction, paper draft and final manuscript formatting. IHR, GGCG and MVRP contributed to data acquisition and curation. JECH made substantial contribution on data interpretation and manuscript revision. SCHR, MP, SS contributed to data analysis. SCHR, SS, NS and MP reviewed the manuscript and interpreted the data. EDV, IHR, EMF

contributed on project conception and data interpretation. All authors listed, have approved the submitted version (and any substantially modified version that involves the author's).

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